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CAMERON STATION, ALEXANDRIA, VIRGINIA

N-63-4.3

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Interim Development Report

for

DEVELOPMENT OF LOW-NOISE TRAVELING-WAVE TUBES

This report covers the period 1 April 1961 through 30 April 1961

MICROWAVE ELECTRONICS CORPORATION
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Navy Department Bureau of Ships, Electronics Division
NObsr-81227, Index Number SS-021001/S. T. 21

CONTENTS

ILLUSTRATIONS

1. ABSTRACT

1.1 The initial design considerations for the low-noise gun were developed during the reporting period. The S-band gun, which gave satisfactory performance, was scaled to L-band, and the calculated noise figure was less than 10 db from 1.0 Gc to 2.6 Gc.

1.2 A broadband helix design was considered in terms of the conditions imposed by the required PPM focusing and broadband noise figure.

2. PART I: TECHNICAL REPORT

2.1 Purpose

2.1.1 Phase II of the contract is for the design and development of L-band low-noise TWT's and for delivery of four final design samples.

2.2 General Factual Data

2.2.1 Identification of Technicians

2.2.1.1 The names of various technical personnel involved in this contract and the man-hours worked are reported in the covering letter accompanying this report.

2.2.2 Patents

2.2.2.1 No patents have been issued during this report period.

2.2.3 References

2.2.3.1 No new references are applicable to this report.

2.3 Detailed Factual Data

2.3.1 Low-Noise Gun Scaling

2.3.1.1 The logical approach to the gun design is to scale the existing S-band gun to L-band. The performance of this gun is satisfactory for a less than 10 db broadband noise figure.

2.3.1.2 By reducing the cathode current density, the normalized plasma frequency at the potential minimum for the L-band gun can be kept the same as that for the S-band gun. This ensures the same initial conditions for both guns.

2.3.1.3 The value of $\overline{Y}$ for the optimum noise standing-wave ratio and phase at the helix entrance is a function of QC and d, which can easily be computed for a known helix design. The general parameters of an L-band helix give a value of approximately 0.8 for $\overline{Y}$, which is the position of the optimum noise figure on the chart of Fig. 1.

2.3.1.4 The results of the gun scaling are also given in Fig. 1, and it can be seen that the noise standing-wave ratio and phase at 1.7 Gc is very nearly optimum. This frequency is slightly higher than the geometric mean and should give good centering. The maximum calculated noise figure is 9.3 db and it occurs at 2.6 Gc.

2.3.2 Broadband Helix Design

2.3.2.1 At the beginning of this program, there was very little information available on operation over bandwidths greater than an octave. The optimum choice for octave bandwidth operation is a range of $1 \leq \gamma a \leq 2$. This range of γa gives a relatively symmetrical dispersion curve and good gain without the use of a large beam-to-helix diameter ratio.

2.3.2.2 In this application, one wishes to use a relatively small beam for several reasons.

2.3.2.2.1 The smaller the beam-to-helix diameter ratio, the easier the focusing. This is an important consideration since this tube is to have a relatively low noise figure in a PPM stack.

2.3.2.2.2 The tube will have environmental requirements. Decreasing the beam diameter will result in performance which is less sensitive to beam size and position. This condition is essential since, under vibration and temperature, a change in the effective beam size and position can be expected.

2.3.2.2.3 To indicate the effect on gain of variation of effective beam size, the change of the beam coupling impedance, with
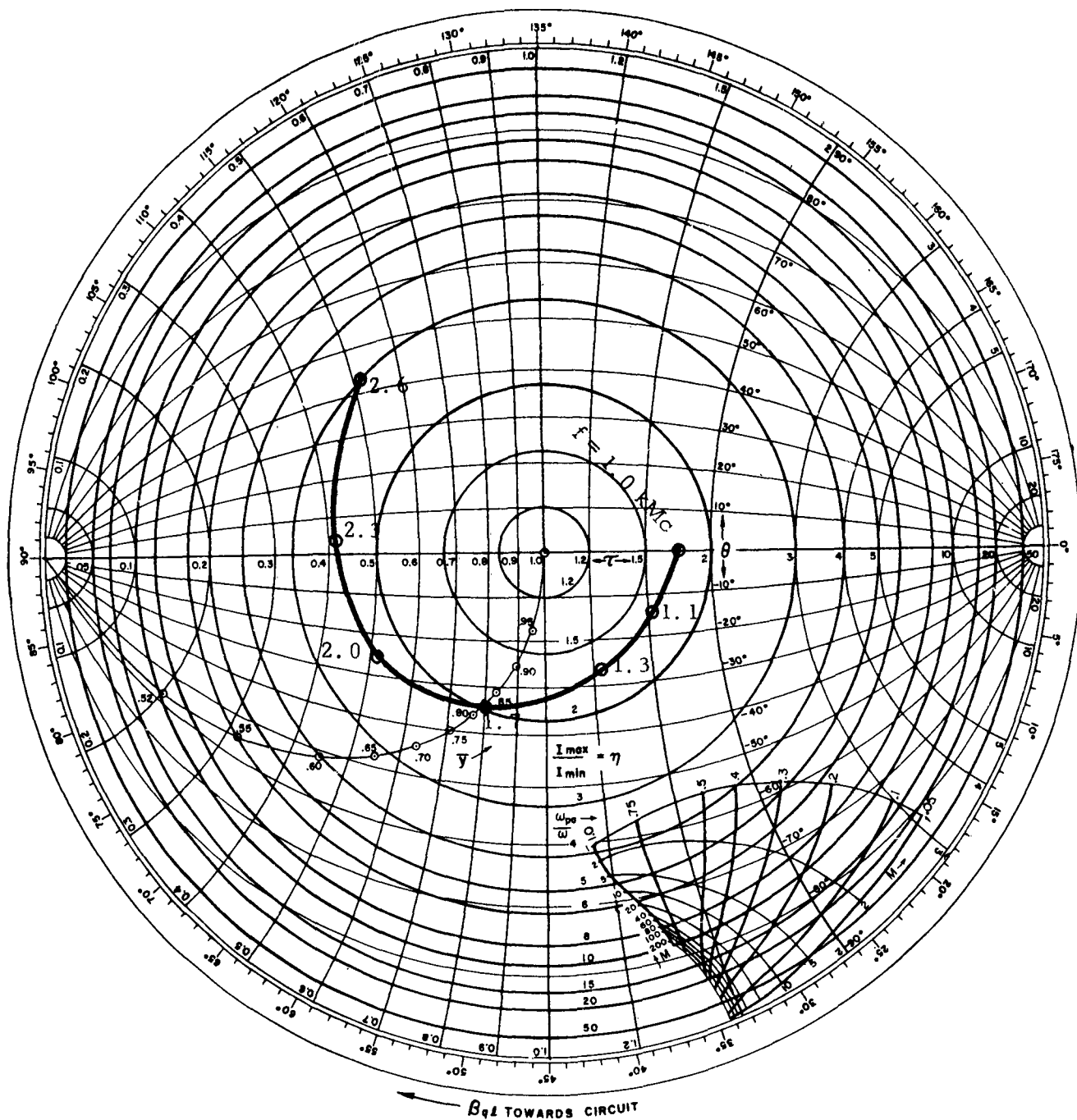
Fig. 1. Noise standing-wave ratio and phase as a function of frequency for the scaled gun.

beam-to-helix diameter ratio, is plotted as a function of γa in Fig. 2.
The calculated results of Fig. 2 confirm that the change in gain with
effective beam size is smaller for lower γa and is less for smaller beam-
to-helix diameter ratios. For instance, at $\gamma a = 2.0$ the $\Delta K/K$ for a b/a
of 0.4 is less than one-third that for b/a equal to 0.8. At the 30 db
gain level, this corresponds to a 1.5 db gain change for a b/a of 0.8.

2.3.3 Helix Design

2.3.3.1 Since γa between 1.0 and 2.0 gives good broadband
gain for a two to one frequency range, the following conditions can be
set down for a 2.6 to 1 bandwidth:

$$\gamma_{low}a = 0.8, \tag{1}$$

$$\gamma_{high}a = 2.6(\gamma_{low}a) = 2.08. \tag{2}$$

2.3.3.2 This choice for the range of γa can be explained by
considering Fig. 3, which presents a plot of the relative increase in
beam coupling impedance and impedance reduction factor for low values
of γa.

2.3.3.3 The lower γa limit can be defined by the crossover
point. This is the value of γa for which a smaller value no longer in-
creases the beam coupling impedance more than it is reduced by the
impedance reduction factor.

2.3.3.4 From Fig. 3, it can be seen that once γa is reduced
below this crossover, the reduction factor rapidly becomes the dominat-
ing factor. This situation is indicated in Fig. 4, which is a plot of the
relative reduced impedance for small γa.

2.3.3.5 These results indicate a minimum value of $\gamma a = 0.7$;
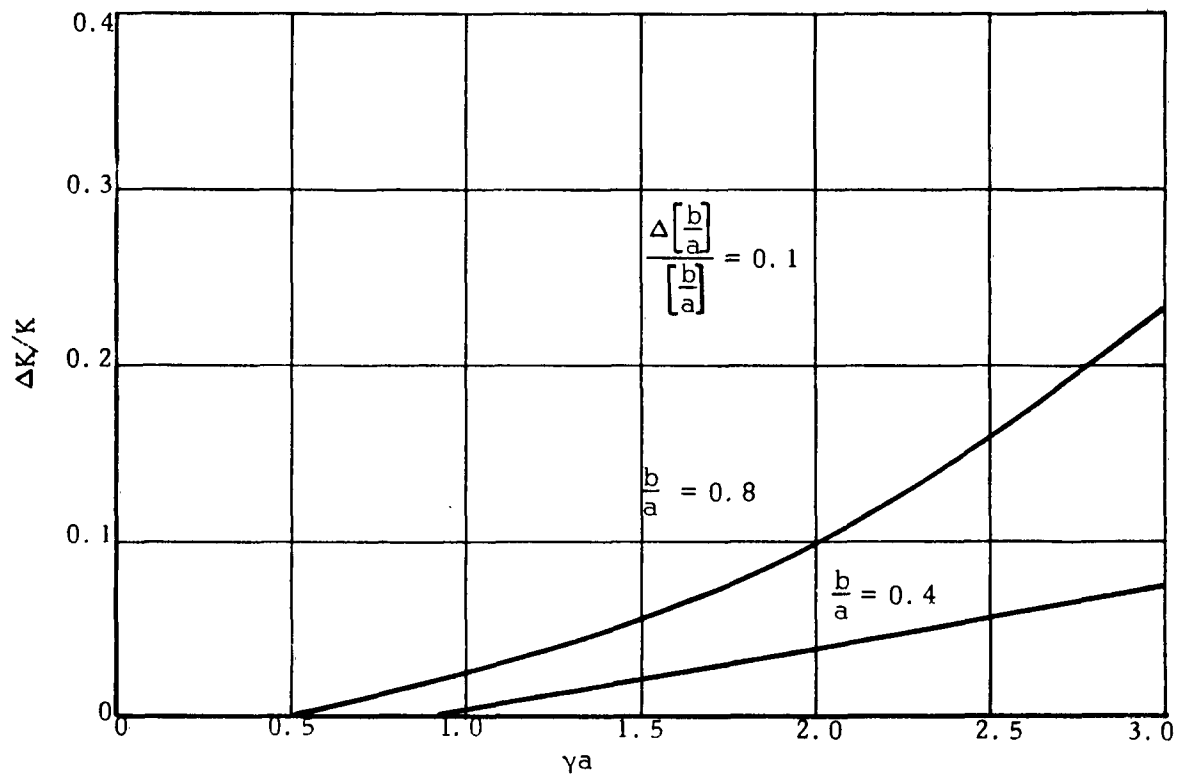therefore, the choice 0.8 is comfortably inside this limit.

Fig. 2. Normalized change in beam coupling impedance as a function of γa and relative beam size.
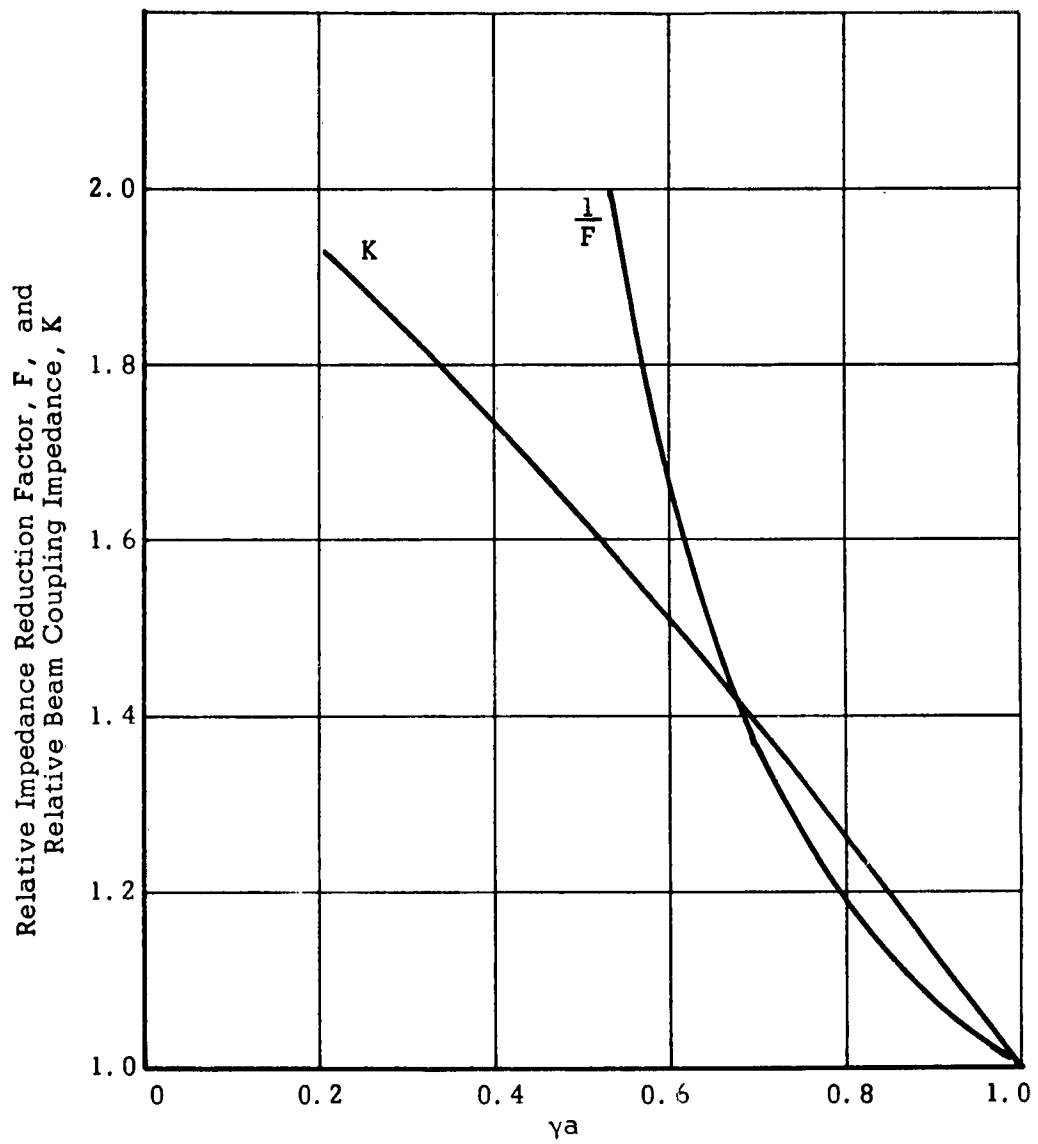
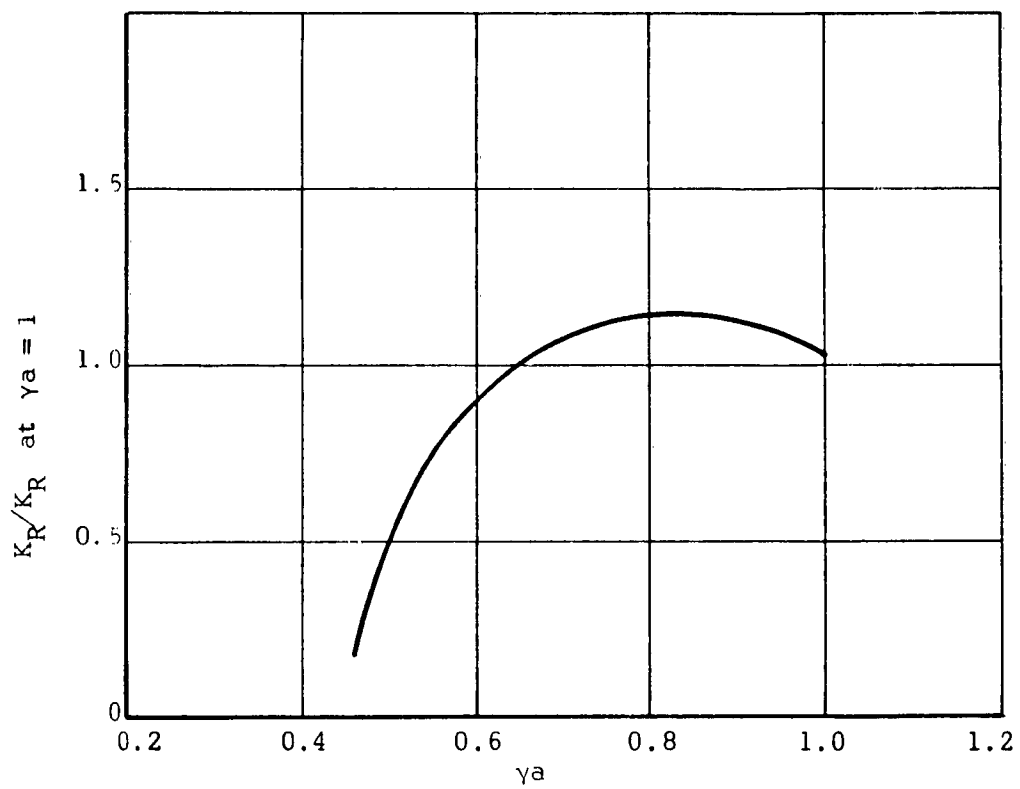Fig. 3. Beam coupling impedance and impedance reduction factor for low γa.

Fig. 4. Relative reduced impedance for low γa.

2.4 Conclusions

2.4.1 A properly scaled S-band gun yields calculated performance which should prove satisfactory for the less than 10 db noise figure required from 1.0 Gc to 2.6 Gc.

2.4.2 A range of γa from 0.8 to 2.08 should give satisfactory broadband performance for gain and power.

3. PART II: PROGRAM FOR NEXT INTERVAL

3. 1 The program for the next reporting period will be composed of:
- completion of low-noise gun calculations and the initial mechanical design,
- broadband helix design, and
- broadband match design.

3. 2 See Fig. 5 for project and performance chart.

MICROWAVE ELECTRONICS CORPORATION

Project Performance and Schedule
Index SS-021001/S. T. 21

Contract No. NObsr-81227   (Report) Date April 1961

Period Covered

1961

TASKS	M	A	M	J	J	A	S	O	N	D	J	F

PHASE II: L-Band Program

I.   Scaling of Basic Vacuum Tube to L-Band ————

II.   Solenoid Testing of L-Band Tube ————

III. Scaling of PPM Assembly ————

IV. Beam Testing (PPM) ————

V.   Constructing and Evaluating Developmental Models ————

VI. Refining Design for Prototype Tubes ————

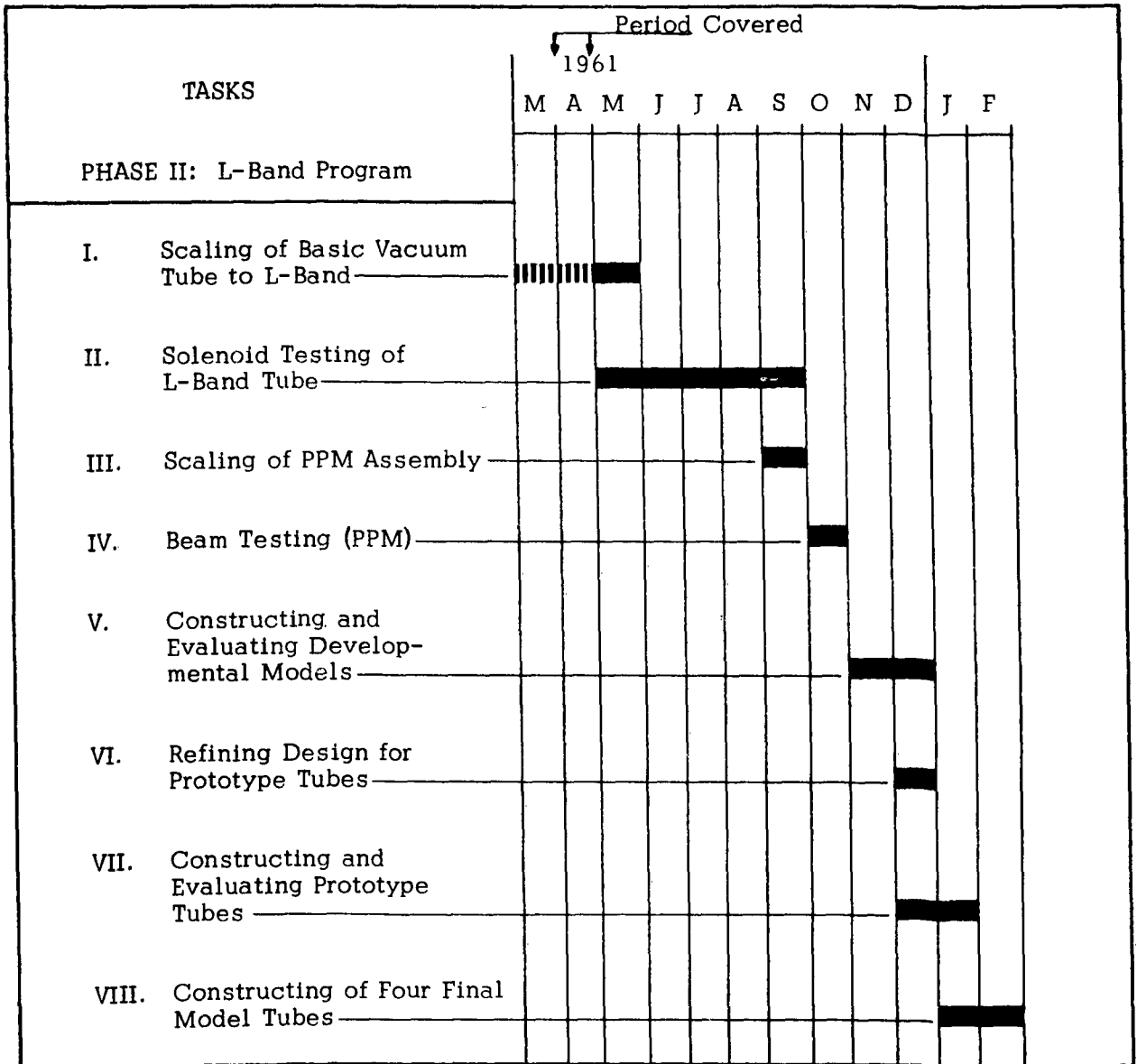VII. Constructing and Evaluating Prototype Tubes ————

VIII. Constructing of Four Final Model Tubes ————

Fig. 5. Project performance and schedule chart.